Report of IASPEI 1st International Workshop on 'Active Monitoring in the Solid Earth Geophysics' (IWAM04): (June 30 - July 2, 2004 in Mizunami city, Japan)

Active geophysical monitoring is a detection and interpretation of rock induced changes in waves, periodically excited by repeated controlled sources. There is little doubt that active monitoring of the time-evolving structures and states in the tectonically active Earth's lithosphere is very important. However, no systematic work in geophysical continuous monitoring has been done so far, because of lack of reliable technology systems other then those generating impulsive signals. In addition to chemical explosives and airguns, the seismic vibrators are also widely used for the above purpose. Nevertheless, the extensive efforts on technological and theoretical developments dealing with vibrators and electro-magnetic controlled sources seem not to be internationally known.

Recent technological advances and growing social demands for public and environmental safety triggered the systematic strategic developments and applications of new methodology for the active monitoring. This conclusion came out from reviewing the extensive works done by Russian scientists since 1976 and by Japanese scientists since 1994 in addition to 'Vibroseis ®' started from 1958 in USA. The essential points of these developments are: (1) use of accurately controlled sinusoidal signal for longer periods of time, which allows effective stacking of data attaining high signal-to-noise ratios, and, (2) availability of better technologies supporting accurate time recording by GPS, stable and accurate control of signal transmitter and data acquisition hardware, computational power for data management, signal processing, etc. One of the critical issues for effective active monitoring is an automated and user-friendly data acquisition system with remote access and data transmission. The potential of the new technology is convincing and will result in a systematic introduction of active monitoring in solid Earth geophysics delivering qualitatively new and important information. It will be used for monitoring, prediction and, eventually, control of disaster mitigation and prevention. Such goals require extensive international and interdisciplinary cooperation.

At the IUGG2003 Meeting held on June 30 - July 11 at Sapporo (Japan), the task group meeting of 'Tectonophysics and Seismic Imaging of the Lithosphere' under IASPEI organized a new task group 'Active Monitoring' for promotion of the active monitoring science and technology as an inter-association agent for IASPEI, IAGA, and IAVCEI. Responding to this decision, Japanese Consortium of Earth's Active Monitoring (JCEAM) was organized in October 2003 by Hiromichi Higashihara of Earthq Res. Inst., Univ. Tokyo (Now, Earthq. Disaster Mitig. Res. Center, National Inst. Earth Sci. Disaster Prev.). As a kick-off meeting towards '**Active Geophysics**', the first international workshop 'Active Monitoring in the Solid Earth Geophysics' (http://www.activemonitoing.org/)(IWAM04) was held in June 30-July 2, 2004 in Mizunami city, Japan as the ISAPEI workshop. More than 100 scientists and engineers attended the workshop from Japan, Russia, USA, China, India, Uzbekistan, Turkey and Argentina. The workshop started from the talk on the above mentioned purpose of the workshop by the chairman of LOC, Naoyuki Fujii of Nagoya Univ. Three overviews from Russia, Japan and China presented the historical background, current state of science and technology and the prospects in each country. They were followed by presentation of eighty papers (fifty eight orals and 22 posters) in seven sessions; 1) Social demands of active monitoring, 2) Strategic consideration, 3) Case study of active monitoring, 4) Technology of active monitoring, 5) Theory of data analysis and interpretation, 6) Imaging of crustal heterogeneity based on scattering approach, and 7) Other topical subjects from structure sensitivity of rocks to active geophysics. In addition to the sessions,

seven poster presentations on scientific studies by local Japanese high school students were presented as outreach activities. One day before the workshop, one Russian and one Japanese attendant to the workshop visited two junior high schools nearby Mizunami city and presented their scientific motivations and personal experiences to the students.

In the first of the sessions, the overview of past and recent research programs using the active seismic and electromagnetic sources in Russian Republic, Japan and China were presented. In Russian Republic, several artificial seismic and electro-magnetic sources have been developed since late 1970. The large Russian seismic vibrators have been used to study the static and dynamic structures of the Earth. In Japan, so-called Accurately Controlled and Routinely Operated Signal System (ACROSS) was developed since 1995. The objective of the ACROSS is to detect subtle changes of the Earth's structure. While application of large force to the ground may destroy the signatures of the seismic source, the ACROSS has been designed to minimize the damage of the ground.

Different types of transmitter design for controlled seismic waves were reported: twin eccentric source rotary generating a sweeping sinusoidal force of ~1000 kN from Russian group, single eccentric source generating a continuous repetition of FM and/or AM signals up to ~200 kN from Japanese groups and a magnetic levitation vibrator up to 50 kN from Argentine. The radiation session from the Russian transmitter usually has duration for about an hour and can be detected at the distance of ~500 km. Japanese system provides transfer function in tensor form including information on polarization anisotropy. The versatility of magnetic levitation vibrator is noted, it can generate any wave form such as binary coded pseudo-random sequence.

Furthermore, a variety of strategies and technologies linked with specifics of these transmitters have been presented: proposal of low friction bearing for rotary machine, synchronization of signals to universal time, optimum design of the signal mode, the stable method of operation, an array design for both transmitters and sensors, and various methods of target-oriented data processing .

Field experiments using seismic vibrators have been extensively conducted in Russia. The experiments in Baikal, Altai- Sayan and Okhotsk-Chukotski regions showed that the reflected and refracted arrivals can be recorded from the deep continental crust at the distance of 500 km from the source. In US, the active monitoring of San Andreas Fault was done from 1987 to 1996 using Vibroseis® source. The observed time variations had strong correlation with seismicity. The monitoring in Awaji and Tono areas is taking place in Japan. The acquired data reveal temporal variations which correlate with other geophysical measurements.

The actual targets of active monitoring are inhomogeneities of various types generated by localized agent such as deformation in the lithosphere and most of the waves observed are scattered wave in actual observation. Several potential theories at the various stages towards the 3D structure inversion were presented which can be utilized in active monitoring.

Theory of 3-D electromagnetic imaging and inversion, scattering-based seismic tomography, and differential seismic waveform tomography were presented with application to the time-lapse data. These studies show high capability for imaging and monitoring of shallow targets. Scattering theory and experiment were reported in their relation to the active monitoring.

Changes of rock properties, such as conductivity and Q factor, complex dielectric permittivity of wet rocks, effects of visco-elastic and visco-plastic properties on deformation were discussed as potential targets for monitoring. In-situ measurement of the liquefaction potential of soils was also demonstrated, as an application of vibrator studies on non-linear effects of repeated deformations and as a possible application to the active control of the ground properties .

In the closing remarks, all of the participants expressed a need in extensive promotion of international cooperation in active monitoring studies and frequent information exchange. A special session on active monitoring in geophysics will take place in

2004 AGU Meeting in San Francisco. The CD of the proceedings of the workshop is available on request to <iam@ml.jnc.go.jp>. More information can be found in to <http://www.activemonitoing,org/> .

Acknowledgments:
This workshop was supported financially by IASPEI, Inoue Foundation, Kajima Foundation, Tokyo Geographical Society, Kao Foundation for arts and sciences, Asahi Glass Foundation, University of Nagoya and University of Tokyo.

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